CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-156

Genoa Fault, Alpine County

by

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INTRODUCTION

The Genoa fault* is identified as an unnamed, northerly trending Quaternary fault by Jennings (1975; see Figure 1). As Dohrenwend (1982a) and Jennings show it, this fault extends from the vicinity of Reno, Nevada, southward to Markleeville and beyond. The segment of the fault within California lies within the Minden, Woodfords, and Markleeville 7.5-minute quadrangles. Other possibly related, apparently normal faults evaluated herein primarily lie east of the main trace of the Genoa fault within the Markleeville, Woodfords, Carters Station, and Heenan Lake 7.5-minute quadrangles.

The Genoa and nearby associated faults are being evaluated as part of a statewide program to identify faults that are sufficiently active and well defined. Faults determined to meet the criteria outlined in Hart (1980) are routinely recommended for inclusion in one or more Special Studies Zones as directed by the Alquist-Priolo Special Studies Zones Act of 1972.

The scope of this investigative effort varied within the area studied. Within the Markleeville, Minden, and Woodfords 7.5-minute quadrangles, the investigation consisted of a review of the pertinent literature, interpretation of aerial photographs, and three (3) days of field reconnaissance. Aerial photographs were not available for the Carters Station and Heenan Lake quadrangles. Also, access to much of the latter two quadrangles is limited by the lack of public roadways. Thus, the effort in these latter quadrangles was limited to a review of the available literature.

*The Genoa fault was named by Bell (1981). Except in an unpublished thesis by Curtis (1951) where part of the fault was referred to as the Carson fault, no other name for the fault has been suggested in the literature. For clarity, the name Genoa fault has been used throughout this FER when referring to the principal fault zone from the Woodfords area northward.

SUMMARY OF AVAILABLE INFORMATION

Genoa Fault

The Genoa fault is a generally north-trending normal fault which lies on the margin of the Sierra Nevada and Basin and Ranges geomorphic provinces. On a grand scale, the boundary between these two geomorphic provinces appears to consist of a series of echelon normal faults. The Genoa fault appears to be a major fault in this chain, with similar faults to the north, in Nevada, and to the southeast, in California (Dohrenwend, 1982a). Many of the faults in this system of frontal faults exhibit evidence of Holocene movement.

Russell (1885, p. 279) first recognized the Genoa fault as a post-Lahontan feature, noting:

> "That portion of the Sierra Nevada fault which defines the western border of Carson and Eagle valleys (sic) has undergone a recent displacement of from ten to thirty feet, as is shown by fresh scarps in earth and gravel, and also by the outflow of heated waters at several localities. The recent scarp in this instance has been followed all the way from near Carson City to beyond Genoa; the full extent of the movement, however, far surpasses these limits."

Lawson (1912) examined the fault from near Genoa southward to the area just west of Walleys Hot Springs, Nevada. He reported that segments of the scarp (including that near Walleys Hot Springs) "appeared to me to be so fresh and so little degraded that I considered it possible that the displacement which caused them might have occurred within the memory of man" (p. 195). However, Lawson sought out the earliest inhabitant of the valley who indicated that the scarps were unchanged since 1854.

Lawson (p. 196) described the fault opposite Walleys Hot Springs as:

> "... (W)here best displayed, a very smooth polished and slickensided, hard, rock surface. The strike of this wall is N. 10° E. and its dip is 65° to the east. The surface is veneered with a thin, even and smooth layer of... travertine.... The top of the scarp has been broken down and at its base is encumbered by loose material so that only about 10 feet of it is exposed in the direction of dip...."

Using a hand level, Lawson measured the height of the scarp as 44 feet in this one location, indicating that the scarp was usually 30 to 40 feet high except where it was partly covered by very recent slopewash or alluvium. Lawson (p. 197) also indicated that the scarp very clearly crosses alluvial fans in the area between Walleys Hot Springs and Genoa.

Curtis (1951) mapped the Genoa fault (he called it the Carson fault) southward from Carson Valley to Silver Creek (south of the area shown on Figure 2C). Curtis' map appears somewhat generalized. His legend indicates that he used only solid and dashed lines for faults, the latter indicating faults that were approximately located or concealed. The Carson fault is everywhere depicted with a solid line across nearly all lithologic units (including younger alluvium, older alluvium, older fanglomerate, and younger fanglomerate). Koenig (1963) used Curtis but depicted the Genoa fault as concealed beneath alluvium and Pleistocene nonmarine deposits near Woodfords.

Moore (1969) agreed with Lawson that the Genoa fault has been recently active. In addition to repeating some of Lawson's observations, Moore (p. 18) also included a photograph of the fault where it is exposed in a quarry about 1 mile south of Genoa. The caption indicates that the fault plane "... separates sheared plutonic metavolcanic rock from recent slope wash."

Pease (1979) concluded that displacement has occurred along the segment of the Genoa fault between Hobo Hot Springs, Nevada, and Genoa, Nevada, in the last 200 to 1000 years. Pease (1980) depicts the Genoa fault as cutting early to middle Holocene fans (upon which soils have been developing for about 5000 years) as well as more recent (probably late Holocene) debris flow deposits. Near Hobo Hot Springs, the Genoa fault appears to bifurcate. The zone northeast of Hobo Hot Springs appears somewhat more complex. Pease (1980) indicates that branches of the Genoa fault have displaced pediments that have entisols which lack distinct pedogenic horizons. Pease (1980) concluded that these pediments were less than 2000 years old. His (1979) earthquake hazard map indicates these same faults northeast of Hobo Hot Springs have been active during the past 3000 years.

Bell and Pease (1980) summarized the age and recency of faulting along the Genoa fault in and south of Carson City. Based on soil stratigraphic relationships south of Carson City, they (p. 594) concluded that: "1) faulting has occurred repeatedly throughout Pleistocene time; 2) at least two periods of fault activity have taken place within the last 12,000 years; and 3) one of the periods of activity occurred within the last 2000–3000 years." Furthermore, they state that more than 120 m of displacement has occurred along <u>one</u> of the faults in the zone since early Quaternary time.

Bell (1981, p. 32-33) referred to the segment of the Sierra Nevada frontal fault system south of the Hobo Hot Springs area as the Genoa fault. Bell indicated that the scarp along the Genoa fault is geomorphically very young, imprecisely [see previous paragraph] citing Pease (1979) as indicating that the scarp may be less than a couple of hundred years old. Bell (citing Pease, 1979) stated that northward of a point just south of Hobo Hot Springs, the fault consists of two main splays, both of which are less than several thousand years old. According to Bell, this complex zone of young faults extends northward to Carson City and beyond. However, scarps within the zone in the Reno area have been trenched and determined to not offset pre-Tioga age soils.

Little has been written about the fault in the area south of Walleys Hot Springs, Nevada. However, several geologic maps have recently been completed. The maps of Armin and John (1980; 1983), Armin and others (1981), John and others (1981), and Stewart and Noble (1979) are reasonably detailed 1:62,500-

scale geologic maps. The remaining maps (Dohrenwend, 1982a; 1982b; and Stewart and others, 1982) are regional compilations based on selected data from the more-detailed maps just cited. This literature review concentrated on the more-detailed maps rather than on the derivative regional maps. Although none of these references include any discussion of the Genoa fault, most of these maps indicate the relationships between the fault and various stratigraphic units. From these relationships, the history of recent displacement may be inferred.

Two maps (Armin and John, 1980; 1983) of the Freel Peak 15-minute quadrangle exist. Both maps depict the Genoa fault as cutting Holocene alluvial fan deposits at the mouth of Mott Canyon (Figure 2A, Section 4, T. 12 N., R. 19 E.). At the mouth of Fay Canyon (Section 35, T. 12 N., R. 19 E.), Armin and John (1980) show the fault as clearly cutting Holocene fan deposits. In contrast, Armin and John (1983) show the fan deposits on the upthrown side as definitely being Pleistocene in age. In addition, both maps show the Genoa fault as approximately located or inferred to cut Holocene fan deposits at Woodfords (Section 35, T. 11 N., R. 19 E.; Figure 2B), although the limits of the fan deposits differ from one map to the other. Elsewhere both maps show the fault as cutting late Pleistocene deposits or as forming the contact between bedrock and Quaternary deposits. Where differences exist between the maps, the 1983 version usually shows the fault as slightly more discontinuous and/or concealed beneath fan deposits. These differences are noted on Figures 2A and 2B.

Armin and John (1980; 1983) indicate that the main zone of the Genoa fault essentially consists of a single trace that locally steps left. One of these left-steps occurs at the California-Nevada border (Figure 2a); another occurs just south of Woodfords (Figure 2B).

The area to the south has been mapped by John and others (1981; note that John, 1983, reports that a new version of this map is in press). John and others do not differentiate between faults that are inferred and those which are approximately located. They depict only one of the faults in the Markleeville 15-minute quadrangle as approximately located in or inferred to cut late Pleistocene deposits. The remainder of the faults in this area either lack any young deposits along their traces or are depicted as concealed by late Pleistocene and/or undifferentiated Quaternary deposits.

In addition to these various geologic maps, a Bouguer gravity map of part of the zone exists (Oliver and others, 1980). It is apparent from this map that the Genoa fault north of Markleeville is fairly well-expressed in the regional gravity. Gravity lows are centered in the Carson Valley and near Woodfords. From near Markleeville southward, the gravity map suggests the fault is not as important a feature.

Other Faults

As indicated earlier, the Genoa fault appears to be part of a system of late Quaternary normal faults which border the western margin of the Sierra Nevada block. To the southeast lies Slinkard Valley, the western margin of which is bounded by an east-dipping normal fault that exhibits clear evidence of late Quaternary activity (John and others, 1981). Another normal fault which exhibits evidence of late Quaternary activity lies to the northeast along U.S. Highway 395 in Nevada (Stewart and Noble, 1979; John and others, 1981).

In the area between the Genoa fault and the two faults near Slinkard Valley and U.S. 395 there are several shorter faults along most of which the movement has been primarily east-side down relatively (Armin and John, 1980; 1983; John and others, 1981; Stewart and Noble, 1979). Unfortunately, the literature does not provide sufficient information to allow the user to determine whether these intervening faults are normal or reverse faults, but given the regional setting it is more likely that they are the former. If so, then the possibility exists that some or all of these faults may be related to the Genoa fault. Therefore, it is appropriate to consider whether or not Holocene displacement has occurred along one or more of these faults.

Armin and John (1980; 1983) depict several faults immediately east of Woodfords as cutting deposits of late Pleistocene and Holocene age (Figure 2B). John and others (1981) show a similar pattern of faulting, however Quaternary deposits are only locally present along some of the faults they mapped (Figure 2C). Where such deposits exist, John and others indicate that these deposits are apparently not faulted. Few of the faults in California mapped by Stewart and Noble (1979) have any young deposits mapped along them (Figure 2D and 2E).

There appears to be a discrepancy at the boundary of Figures 2B and 2D. Armin and John (1980; 1983) indicate that a northeast trending fault cuts Holocene deposits near the boundary of the quadrangle; however, Stewart and Noble do not show such a fault on their map.

INTERPRETATION OF AERIAL PHOTOGRAPHS

U.S. Geological Survey (1973) aerial photographs of that portion of the study area within the Minden, Woodfords, and Markleeville 7.5-minute quadrangles were steroscopically interpreted in order to detect geomorphic features indicative of recent fault rupture. Well-defined scarps are present locally along the Genoa fault. In some places in Nevada, these scarps very clearly cross alluvial fans and other recent deposits (i.e., the fan at the mouth of Mott Canyon; Figure 3A; Section 4, T. 12 N., R. 19 E.). In California, between Voight and Stuard Canyons (Figure 3B; Sections 23 and 26, T. 11 N., R. 20 E.) possible scarps across older fans are evident on the photographs interpreted. Locally there appears to be more than one scarp (such as near Jobs Canyon, Figure 3A; Sections 21 and 22, T. 12 N., R. 19 E.).

Near Woodfords (Figure 3B), a well-defined scarp appears to cross the alluvial deposits along Carson Creek. This scarp appears to die out to the south near Washoe Cemetary. To the southeast near Diamond Valley School, a second scarp, subparallel to the last noted, is evident across what appeared to be glacial morrainal debris. Farther south, a tonal lineament which coincides with a saddle is evident on the photographs; however, no scarp is evident in the bedrock.

Five scarps are evident in Diamond Valley east of Diamond Valley School. However, these scarps appear to be confined to the Quaternary deposits, suggesting that they might not be recent faults but could have originated by some other process or could be older, armored scarps (see also the section on field observations). Other lineaments, some of which may coincide with low scarps, are locally evident in bedrock areas north and south of Diamond Valley. One very well defined scarp (DV9 on Figure 3B) is very likely a normal fault. When compared, the scarps in Diamond Valley and DV9 are quite similar, suggesting that the pattern of fault rupture in future events in this area is likely to be similar — that is, rupture is likely to occur on a series of short, discontinuous faults. Numerous tonal lineaments are evident in the areas of volcanic bedrock around Diamond Valley, but these lineaments were not plotted unless they partly coincide with other, more diagnostic features.

Near Paynesville (Figure 3B), a high, well-defined, slightly dissected scarp is quite evident. It appears that this scarp has been drowned locally by more recent fan deposits to the north. This suggests that the scarp is probably a very old (middle to late Pleistocene) feature.

As noted earlier, two maps of the geology of the Freel Peak 15-minute quadrangle exist (Armin and John, 1980; 1983). Locally these two version differ. In an attempt to determine which map appears more accurate, the results of the photointerpretation were compared with each map. Based on this comparison, it appears that Armin and John (1983) is probably better. For example, on the photographs it does not appear that a Holocene fan is offset at the mouth of Fay Canyon (as suggested by Armin and John, 1980). Similarly, Armin and John (1983) show the Genoa fault as locally discontinuous and locally concealed in places where Armin and John (1980) show the fault as continuously exposed. The results of this photointerpretation more closely aggree with the former rather than the latter in these areas.

Based on the photographs interpreted, it appears that the Genoa fault zone extends southward into the Markleeville quadrangle, but that the displacement along the fault has been less than that to the north. However, there are scarps, troughs, and local closed depressions which suggest that relatively minor, distributive faulting has occurred in the area during late Quaternary time. Many of these features are plotted on Figure 4C, but many other similar features which may also be due to minor recent faulting have not been plotted. Most of these fault features are in older bedrock and no Holocene deposits appear offset. It is extremely difficult to determine precisely which of these faults have been active during the Holocene. However, some of the features appear more continuous and are better defined than others.

RESULTS OF FIELD RECONNAISSANCE

Approximately three days were spent in the field as part of this fault evaluation effort. Because the fault appears to be best defined at the mouth of

Mott Canyon (Figure 2A), this field work extended slightly into Nevada.

Conditions at Mott Canyon are as one might expect for a canyon which is crossed by a major normal fault. A north-trending scarp about 40 feet high interrupts an alluvial fan (which Armin and John, 1983, show as Holocene in age) at the mouth of the canyon. At its steepest point, the scarp slopes about 44 to 45 degrees eastward. The stretch of the creek beginning about twenty feet upstream from the crest of the scarp and extending downstream to the foot of the scarp is marked by a waterfall and rapids. Boulder conglomerates over a completely decomposed granite are well exposed in a stream cut. This granite is completely sheared. The largest chunks of granite apparent in outcrop measured 2 inches in the longest direction. Although this pulverized bedrock is only a few feet upslope from the escarpment, no exposure of fan deposits on the downthrown side in fault contact was available. Such a relationship may be easily inferred, however. A few of the more well-defined shears dip approximately 81° east, but many less well-defined shears are more horizontal; the principal steep shear observed is on trend with the crest of the scarp. There appears to be very little soil developed on the sheared material. The soils on the fan deposits on the downthrown side have reddened somewhat. Biotite-rich boulders in the fan deposits on the down-side of the scarp are quite crumbly suggesting that they are probably late Pleistocene or earliest Holocene in age. The area is quite shady and fairly moist. Some of the boulders are 40 to 80% covered by black lichen. A little horst appears in the upthrown block within a few feet of the scarp. The soil on the upthrown block about 3 inches below the surface is 2.5Y 6/4 or 5/4 (dry) on the Munsell Soil Color chart.

Although the available exposures at Mott Canyon did not expose a fault in the stream gravels, the features observed were consistent with a postulated recently active fault, the main slip plane of which should be located immediately east of the stream cut exposure. The scarp at this location has not been degraded significantly, and the boulders on the scarp lack a significant cover of lichen. The thinness of the colluvial material (derived from the stream terrace deposits on the upthrown block) which covers the scarp, along with the relative freshness of the boulders in the colluvium, suggest that movement has occurred along the Genoa fault in this location in latest Holocene time.

In California, the evidence for the existence of a Holocene-active fault is less impressive, but locally present along the Genoa fault. At the boundary between Sections 23 and 26 (Figure 3B), an alluvial fan was identified as possibly being offset based on the aerial photographs interpreted. The older fan above this apparent offset slopes 18 degrees eastward. Below the crest of the escarpment, the slope averages 23 degrees for a distance of about 200 feet. Locally this escarpment is much steeper. Conceivably, some of this steepening could be due to stream erosion cutting off the base of the fan. However, the streams currently are far enough removed from the steeper portion, suggesting that the scarp results from faulting. The modern stream channel appears to steepen slightly, suggesting the western block has been elevated relative to the eastern block. The older fans have granites and gneisses. Some of these granite boulders have been significantly weathered, giving a "ragged" look to them. A few boulders in the area of the scarp have some black lichens (circles about

1" in diameter); however, most boulders in this area lack such lichen. Away from the scarp, the lichen cover on the boulders is more extensive and the boulders are much more weathered. The soil on the surface of the upper fan appears a golden-red suggesting that it is an older fan. On the south side of the main stream channel, the escarpment across the fan steepens to 35 degrees at one point and is about 40 feet high. However, this portion of the scarp appears erosional in origin. No exposures were apparent in this vicinity.

Attempts were made to find the nearby sites to the north and south where it appeared on the photos that the older fans were offset. The possible offset fans in the southeastern 1/4 of Section 23 were not confirmed on the ground. The fan at the mouth of Voight Canyon (Section 26) was also checked, but the surface of the fan has been graded for a housing development.

At Woodfords, a scarp 38 feet high is apparent in the field as well as on the aerial photographs. During the field reconnaissance it became apparent that part of the scarp has been buried under a roadfill, and that access roads have been bladed across and along other parts of the scarp. The height of the scarp was measured a few tens of feet southeast of the Carson River, in an area covered by alluvium (probably Holocene but currently removed from the influence of the stream except during catastrophic floods). Scarp width was difficult to estimate due to vegetation, but appeared to be about 200 feet from toe to crest. The crest did not appear sharply defined, but may have been modified by man as well as catastrophic flood events.

As indicated earlier, Jennings (1975) depicts the Genoa fault as extending southward to Grover Hot Springs State Park and beyond (Figure 2C). Except for the area within and near the park, time did not permit a reconnaissance of the terrain west of State Highway 89 between Woodfords and Markleeville since gates across all access roads (except that leading to the park) were locked. At Grover Hot Spring State Park, Armin and others (1981) show one large Holocene fan, but there are actually several small fans evident. No scarps were observed across any of the alluvial fans. Apparently the fault mapped passes beneath these fans. The Hot Springs are not located along this fault, and thus should not be used as direct evidence of the activity of this particular fault.

Armin and John (1980; 1983) mapped several faults as cutting Pleistocene outwash deposits in Diamond Valley. The field observations along each will be described beginning with the fault (DV1 on Figures 2A and 3A) located near Diamond Valley School and progressing generally eastward.

Scarp DV1 (Figures 2B and 3B) was examined near Diamond Valley Road. Here the scarp appears quite broad and is somewhat dissected. The height of the scarp varies from about 15 to 30 feet, and appears to be confined to alluvial deposits which may be late Pleistocene (or older based on the reddish soils) in age. To the south (Figure 2C), Armin and others indicate this fault is concealed by Holocene deposits. No scarps were evident along this mapped fault either in the area of these Holocene deposits (Section 5) or adjacent to Curtz Lake in volcanic terrain.

Scarp DV2 appears to coincide with the contact between older alluvium on the west and younger valley fill to the east. The feature is not sharp — there is a noticeable (about 40 feet) change in elevation, but the scarp itself has been degraded so it is now about 200 feet wide. Glacial eratics exposed on the face of the scarp are largely covered by black lichen, suggesting that significant fault movement has not occurred here during the latest Holocene. Large boulders in the deposits west of the scarp may have armored the scarp somewhat.

Scarp DV3 does not appear to be very well-defined near Diamond Valley Road, in part because of the stream which runs at the base of the scarp and which crosses it obliquely in Section 36. Armin and John (1980; 1983) indicate that this scarp is evidence of a fault which cuts late Pleistocene outwash deposits. No scarp was evident in the volcanic terrain north of Diamond Valley.

Scarp DV4 crosses Diamond Valley Road (Figure 2B and 3B) strikes about N 20° E. Locally a stream runs along the foot of this scarp, and may have added about 2 to 3 feet to the height of the scarp. This scarp is about 13 feet high and 70 to 90 feet wide depending on location. There is a slight swale on the upper block with another slight rise (scarp) of about 4 feet located a few hundred feet west of scarp DV4. This swale could be a relict drainage feature. The trend of the swale is a bit more northeasterly than scarp DV4 and empties out over the face of the scarp north of the Diamond Valley Road.

To the east, Armin and John (1980; 1983) show a short fault (DV6). The scarp nearest to their fault is 10 feet high and about 60 to 70 feet wide. The face of the scarp slopes about 6 degrees at its steepest point. It appears the fault shown by Armin and John is located a little too far east based on the new topographic map. The base map shows a short-dashed line (a ditch). The crest of scarp DV6 occurs 1 or 2 feet west of the north-south segment of this ditch.

Scarp DV5 (Figure 3B) appears to be a companion to scarp DV6. The upthrown block appears to be tilted westward forcing the drainage westward to the base of scarp DV6. Scarp DV5 appears more moundlike (a warp?) than scarp DV6, and seems to increase in height to the south. To the east of DV5, there is a noticeable drop of about 5 feet. However, the downthrown block does not appear to be noticeably backtilted.

Armin and John (1980; 1983) depict two faults (DV7 and DV8, Figure 2B) as extending into the valley fill on the north side of Diamond Valley. However, no evidence of any scarps extending out into the valley fill was detected in the field.

I was unable to detect fault DV9 (Figure 2B) of Armin and John (1980; 1983) along Diamond Valley Road at either the northern or southern crossing, although a scarp does locally exist in Section 29. They mapped this fault as cutting glacial outwash deposits in Diamond Valley. Where their fault DV9 crosses Indian Valley Road (southern crossing), maintainance workers had recently bladed a cut across a curvilinear, mound-like feature. Based on this exposure it appears that this feature is a glacial moraine and not a fault-produced topographic feature. This moraine is not evident north of Indian Creek, and there is no scarp or noticeable change in elevation of the valley fill along the fault they depict crossing the valley.

Fault DV9 (Figure 2B) reportedly trends southward along Scossa Canyon. The canyon has been modified by road crews during construction. Conditions are such that it is difficult to determine whether there is or is not a fault in the canyon, let alone determine whether or not alluvial deposits have been affected. Bedrock here is a volcanic breccia. No well-defined fault was observed in any roadcuts.

At the north end of Scossa Canyon, Armin and John (1980; 1983) show a branch fault (DV10) cutting Holocene deposits. This fault supposedly heads northeastward along Indian Creek, connecting Diamond Valley with Dutch Valley. No evidence was observed that any Holocene stream or fan deposits are cut by the fault. The dashed fault shown by Armin and John (1983) as cutting Holocene fan deposits approximately coincides with a road. Only here was a scarp-like feature apparent, but this feature almost certainly is the product of grading (or is highly man-modified).

Where branch fault DV11 (Figure 2C, site DV11a) supposedly crosses Airport Road south of Indian Creek Reservoir, there is no evidence of any scarps on either side of the road or across what appears to be a small alluviated flat. There is no well-defined drainage in this area except for a man-made ditch. According to Armin and John, the fault crosses the road a total of three times (sites DV11a, DV11b, and DV11c) south of Indian Creek Reservoir; however, no evidence of any fault scarps was apparent in the volcanic terrain at sites DV11b and DV11c. The fault, if it exists, appears to be entirely within the volcanics, is not well-defined, and cannot be shown to have been active during the Holocene.

Access to the many scarps and faults mapped by Armin and others (1981) in the Markleeville quadrangle (Figure 3C) is limited. Time did not permit field checking of many the features located in the more remote areas of the quadrangle. As indicated on Figure 3C, several of the faults mapped by Armin and others were checked, but most laked well-defined scarps. A notable exception was fault GHS, along which a well-defined scarp about 5 meters high was noted. Parallel to and a few feet east of this scarp was a second, lower, well-defined scarp about 1.5 meters high. The faces of these scarps slope 28[and 32[east, respectively, have sharp crests, and are not noticeably dissected. However, these scarps are underlain by volcanic materials in most places and would be expected to be preserved for a long time. The alluvial deposits (latest Holocene in age) along Hot Springs Creek lacked any noticeable scarps. The ponded alluvium in Section 18, T. 10 N., R. 19 E., was not field checked.

SEISMICITY

Despite the fresh appearence of the scarp along the Genoa fault noted by Lawson (1912) and subsequent workers, few large earthquakes have occurred along the zone during historic time. Real and others (1978) report only two earthquakes larger than magnitude 4.9 occurred along this zone in California between 1900 and 1974. VanWormer and Ryall (1980) determined that the focal mechanism of the 1978 Diamond Valley earthquake was right-lateral or left-lateral, respectively, on a nearly vertical, northwest- or northeast-trending strike slip fault.* Toppozada and others (1981) reported that several major earthquakes occurred in the late 1800's in the area north and northeast of Genoa.

TABLE 1. Epicenters of selected earthquakes larger than 5.0 near the Genoa fault since 1900 (after Real and others, 1978; Ryall and Ryall, 1980).

DATE	LATITUDE	LONGITUDE	MAGNITUDE	DEPTH
12/17/1942	38.870	119.900	5.1	NA
3/22/1953	38.820	119.980	5.0	NA
9/04/1978	38.82	119.77	5.2	5.8 km

Cockerham (1982; 1983) reports a few earthquakes larger than M 1.5 have occurred in a cluster in the vicinity of the southern end of the Genoa fault since 1980.

CONCLUSIONS

Based on the literature reviewed, the aerial photographs interpreted, and the limited field work completed as part of this evaluation, it appears that the Genoa fault is a major, easterly dipping, normal, range-front fault along which movement has (at least locally) occurred during late Holocene time. Pease (1979) suggests that such movement has occurred during the past 2000 years. Lawson (1912) and subsequent workers have verified the existence of a very fresh-looking fault scarp which locally exceeds 40 feet in height near Genoa.

The Genoa fault has been mapped southward into California as a slightly discontinuous zone of normal faults (Armin and John, 1980; 1983). Deposits of probable Holocene age have been offset at the mouth of Mott Canyon (Nevada), less than three miles from California (Armin and John, 1980; 1983; Smith, this FER). Similarly, a reasonably well-defined scarp across the deposits of West Carson River suggests that recent (probably Holocene, and most certainly as recent as latest Pleistocene) displacement has occurred along the Genoa fault near Woodfords. Between Mott Canyon and Woodfords, the location of the main fault zone is largely inferred based on the geomorphic features shown on Figures

* Also see Somerville and others (1980) on the September 1978 earthquake sequence in Diamond Valley.

3A and 3B. Branches of the fault appear to extend southward of the Woodfords area into the Markleeville quadrangle. While Holocene activity cannot be demonstrated on many of these feature, the presence of ponded alluvium along one scarp (Figure 3C, Section 18, T. 10 N., R. 20 E.) and closed depressions along another (e.g., Curtz Lake) strongly suggests that the most recent displacements are Holocene in age. Some of these fault-produced features are well defined although somewhat discontinuous locally.

Several scarps are present in the Diamond Valley area east of Woodfords. At least some of these (DV1, DV2, DV3, DV4, DV5, DV6, and DV9) are the result of late Pleistocene and probably Holocene fault displacement. Other faults postulated by Armin and John (1980; 1983) and John and others (1981) appear to lack clear evidence of Holocene or latest Pleistocene displacement. For example, field evidence was lacking for DV10, and Stewart and Noble (1979) failed to note any evidence of a fault to the east on trend with DV10. Even the seven faults which have evidence of Holocene or latest Pleistocene displacement and are locally well defined do not appear to be as continuous as shown by Armin and John (1980; 1983) or Armin and others (1981).

Although it cannot yet be demonstrated that displacement occurred along any of faults DV1 through DV6 and DV9 during Holocene time, it is apparent that these faults are related to the Genoa fault. It appears, based on the regional mapping available, that the Genoa fault lies on the margin of the Basin and Range Geomorphic Province, and is part of a system of master, normal faults. It is not atypical of such faults to die out near their ends, and to have numerous, smaller, associated faults nearby. Also, it appears reasonable to expect that relatively minor, but still active, normal faults might exist within the area between two major normal faults. Faults DV 1 through DV6 all lie between the apparent southern end of the active Genoa fault and the Antelope Valley fault (determined to be active by W.A. Bryant (oral communication, 1984). However, these 6 faults all appear to be relatively short, have maximum latest Quaternary displacements of a few feet to a few tens of feet, and are not well expressed in the nearby bedrock areas. The latter makes it difficult to determine 1) whether any of the many fractures in the volcanic bedrock are or are not an active fault, and 2) where such fractures cease to have had Holocene displacement.

In the Markleeville quadrangle, there are scarps, troughs, and local closed depressions which suggest that minor, distributive faulting has occurred in that area during late Quaternary time. Since most of these fault features are in older bedrock and no Holocene deposits are offset, it is difficult to determine precisely which faults have been active during the Holocene. However, the features observed indicate that the region south of Woodfords is undergoing distributive tectonic extension very similar to that which has occurred to the north during the Holocene. Therefore, it is quite likely that Holocene displacement has also occurred along some of these related faults. However, any future faulting is apt to be minor (relative to that expected near Woodfords) and distributive.

RECOMMENDATIONS

Based on the information summarized above, it appears that the Genoa fault should be zoned within the Woodfords and Minden quadrangles. Also, segments of the seven related late Quaternary faults (DV1 through DV 6, and DV 9) in and near Diamond Valley should be zoned. In the Markleeville quadrangle, zoning should be limited to the faults indicated on Figure 4C. No other faults are recommended for zoning at this time.

The faults recommended for zoning are shown on Figures 4A, 4B and 4C. References that should be cited as sources for fault data are indicated on the captions for the individual figures.

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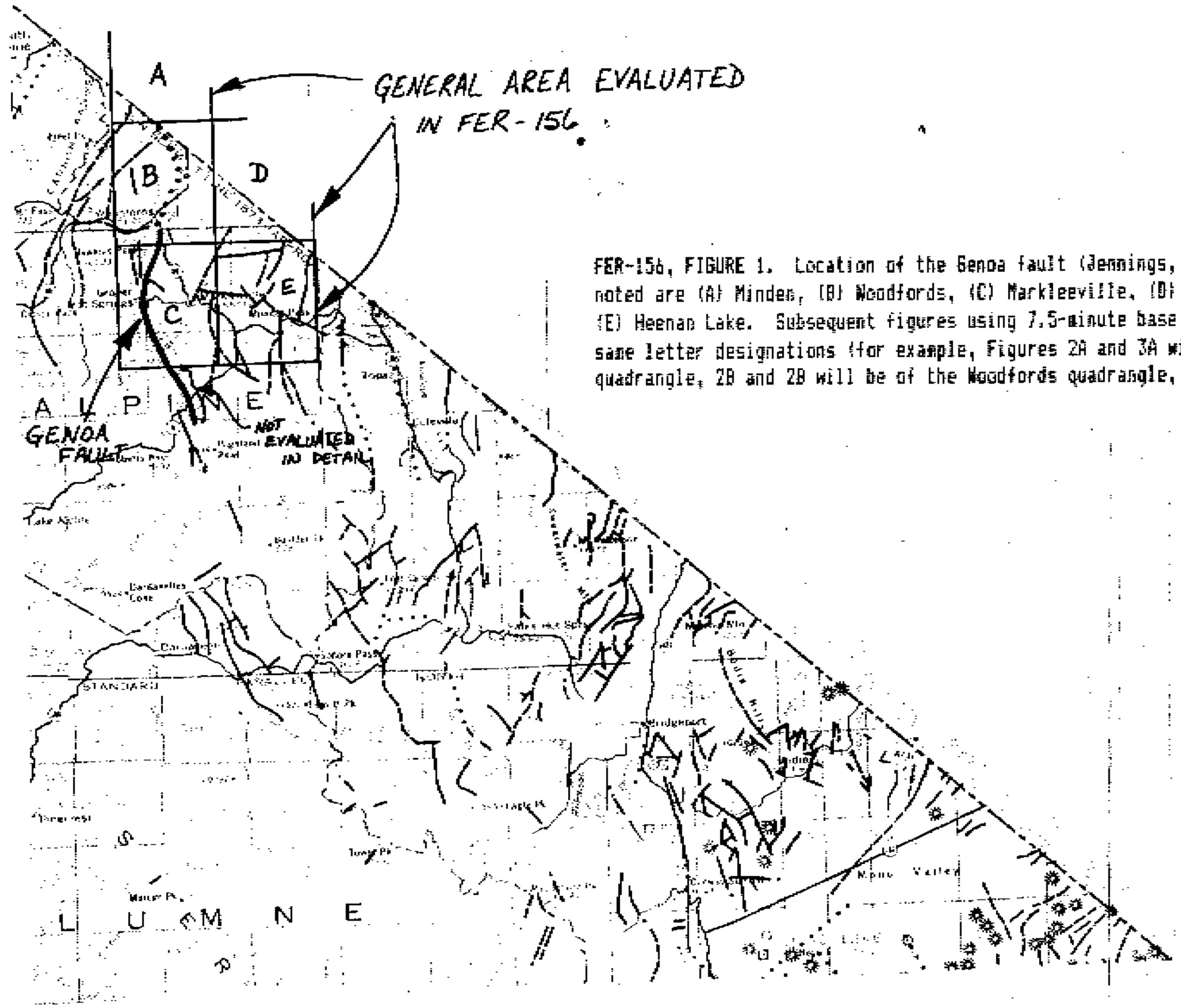

FER-156, FIGURE 1. Location of the Genoa fault (Jennings, 1975). Quadrangles noted are (A) Minden, (B) Woodfords, (C) Markleeville, (D) Carters Station, and (E) Heenan Lake. Subsequent figures using 7.5-minute base maps will use these same letter designations (for example, Figures 2A and 3A will be of the Minden quadrangle, 2B and 2B will be of the Woodfords quadrangle, etc.).

FER-156, FIGURE 4A. Recommended Special Studies Zones, Minden quadrangle. Faults based on Armin and John (1983) and this FER.